ELSEVIER
CrossMark
Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 48 (2014) 991 – 996
Energy Procedia

SHC 2013, International Conference on Solar Heating and Cooling for Buildings and Industry
September 23-25, 2013, Freiburg, Germany

German/Egyptian demonstration project on solar cooling in a hot arid climate

Peter Schwerdt[a*], Ahmed Hamza H. Ali[b]

[a]*Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT*
Osterfelder Straße 3, 46047 Oberhausen, Germany
[b]*Department of Mechanical Engineering, Faculty of Engineering, Assiut University,*
Assiut 71516, Egypt

Abstract

In Egypt, like in other hot arid countries the use of conventional electrically driven chillers for air conditioning (AC) is increasing dramatically, thus leading to high costs, power grid overload and blackouts. Thermally driven refrigeration processes would offer a perfect alternative to convert solar heat radiation into cooling energy for indoor thermal comfort. The practical feasibility of a solar powered AC system was proven in a successful demonstration project of Fraunhofer UMSICHT, Germany and Assiut University, Egypt. It included the system simulation, design, setting up and operation of an integrated solar operated residential scale cooling system. The project aimed at testing, monitoring and evaluating the thermally driven cooling process under the challenging operating conditions of the upper Nile valley. The Assiut solar cooling system has been successfully operating since summer 2012, and is the first of its kind in Egypt.

Selection and peer review by the scientific conference committee of SHC 2013 under responsibility of PSE AG

Keywords: Adsorption chiller; solar cooling; system design; hot arid climate; heat rejection

* Corresponding author. Tel.: +49-208-8598-1173 ; fax: +49-208-8598-1450 .
E-mail address: peter.schwerdt@umsicht.fraunhofer.de

1876-6102 © 2014 The Authors. Published by Elsevier Ltd.
Selection and peer review by the scientific conference committee of SHC 2013 under responsibility of PSE AG
doi:10.1016/j.egypro.2014.02.113

1. Introduction

Air conditioning of offices and residential buildings is essential in Egypt, as most of its population is living in hot and humid or arid areas. Moreover, new settlements for the growing population will be built in the desert. Like elsewhere in the world, the use of conventional electrically driven chillers is increasing dramatically, thus leading to high costs, power grid overload and blackouts. Consumption of fossil energy is growing further instead of being reduced. As an alternative, solar powered air conditioning (AC) systems are perfect to convert solar heat radiation into cooling energy for indoor thermal comfort, because the solar power is mostly in line with the cooling demand [1]. A successful demonstration project of Fraunhofer UMSICHT and Assiut University has proven the practical feasibility of this technology.

2. Cooperative applied research

The cooperative research project started in 2009, supported by the German-Egyptian-Research-Fund (GERF). It included the system simulation, design, setting up and operation of an integrated solar-operated residential scale cooling system. The project aimed at testing, monitoring and evaluating the thermally driven cooling process under the challenging operating conditions of the city of Assiut, located in the upper Nile valley.

The partners from Assiut University and Fraunhofer UMSICHT shared the main tasks like the system layout, detailed engineering, mounting and system start. The project involved scientists, engineers, student teams and an experienced local contractor.

The Assiut solar cooling system has been successfully operating since June 2012, and is the first of its kind in Egypt [2].

3. System specification

The system schematic diagram is shown in Fig. 1 and consists of mainly of four water circuits which are: the hot water and the cooling water circuit, the chilled water and the cold load circuit. The hot water system consists mainly of the solar collector field (1), a hot water storage tank (2) and pumps. Directly connected, the solar circuit is loading the buffer tank with heating water and/or feeding the chiller. The chilled water loop consist of the chiller itself (3), a cold storage buffer (4) and pumps. The cooling water cycle includes the roof mounted cooling tower (5), a heat exchanger and pumps. Finally the cold load consists of a water cycle with two fan coils (6) and a pump.

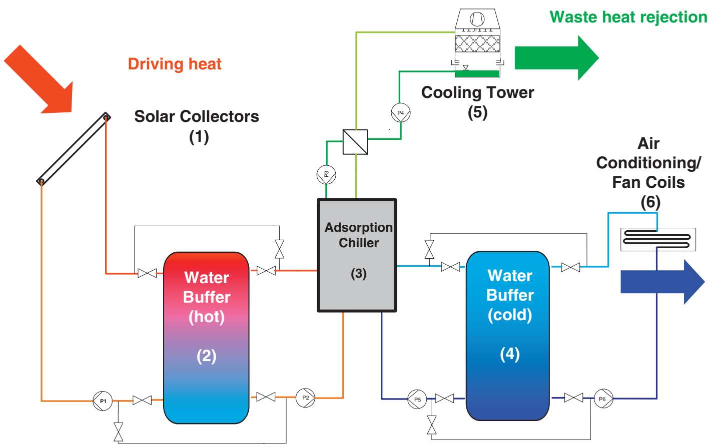

Fig. 1. Process diagram of the Solar Cooling System.

3.1. Solar collector field

CPC vacuum tube collectors of 40 m² are roof mounted on the lab building as shown in Fig. 2. They are arranged in two arrays, each consisting of nine collectors of 2 m^2 each. The collector area is tilted to the roof by 22˚.

Fig. 2. CPC Vacuum tube collectors.

3.2. Hot and cold storage tanks

The thermal buffer system for hot and chilled water is composed of two tanks. The hot water tank has a volume of 1.8 m^3. This tank stores and buffers the hot water from the solar collectors and supplies hot water to the chiller, The cold tank with 1.2 m^3 acts as a storing and buffer supply of the chilled water to the load circuit. The buffer tanks are shown in Fig. 3a.

Fig. 3. (a) Buffer tanks for hot water (left) and chilled water (right); (b) Heat driven adsorption chiller.

3.3. Chiller

The adsorption chiller, as shown in Fig. 3b, was manufactured by SorTech, Germany. It is driven by hot water and has a nominal cooling capacity of 7.5 kW. The compact chiller comprises an evaporator, two fixed-bed sorption chambers and a condenser. Together with the pumps, mixing valves, heat exchangers, meters, sensors and control board it is located in the seminar room of the faculty, being used for room cooling, but also for education and technical training.

Key data[3]:

- Refrigerant: water
- Adsorbent: silica-gel, batch-wise operation with two beds
- Water as transport media for heat and cold loads
- Temperatures:
  - T heating water ~60-85°C (HT)
  - T chilled water ~15-18°C (LT)
  - T cooling water ~30°C (MT)
- Weight: 260 kg

3.4. Cooling tower

The cooling tower, mounted on the roof of the Lab Building, is used to reject the heat from the chiller cooling water to the ambient air. Its rated cooling capacity is 34 kW at 35/30˚C, at ambient air wet bulb temperature of 24˚C.

To ensure a safe make up water supply over the whole day, an additional daily service tank was installed besides the cooling tower.

Fig. 4. Open cycle evaporative cooling tower with feed water storage (left).

3.5. Cold load

The Heat Lab´s floor space of about 90 m^2 is air conditioned by the installed plant, using 2 fan coil units of 4.8 kW cooling capacity each. They are supplied by chilled water from the cold buffer tank, therefore being able to meet the cooling load of the Lab also after sunset.

3.6. Control system

Due to the R&D character of the project, the solar cooling system is monitored by more than 60 sensors (for water flow, temperature, pressure, humidity, radiation), all connected to a data logger, where the data are recorded and forwarded to a PC for visualization. The logger also includes all control circuits, alarms and a LAN based remote access.

4. Results

The system was put into operation in June 2012, followed by adjustment and optimization of process parameters, minor modifications and installation of some additional parts, such as a day buffer tank for cooling tower make up water.

At challenging summer operating conditions with high solar radiation (daily max. ~950 kW/m²) and air temperatures often exceeding 40°C, all subsystems were working as planned. The solar collector heat output reached up to 35 kW, with an efficiency of ~50 to 65%. Nevertheless, the air pollution (dust) required weekly cleaning of the CPC collectors to prevent significant performance reduction.

The temperature stratification in the hot water buffer was excellent and stable during the day. The buffer allowed an intermittent solar circuit flow while the chiller was supplied with a constant driving heat temperature.

Depending on the load and chilled water inlet temperature the chiller delivered cold water (LT) in the range of 7-20°C, with ~15-18°C under nominal conditions (Fig. 5).

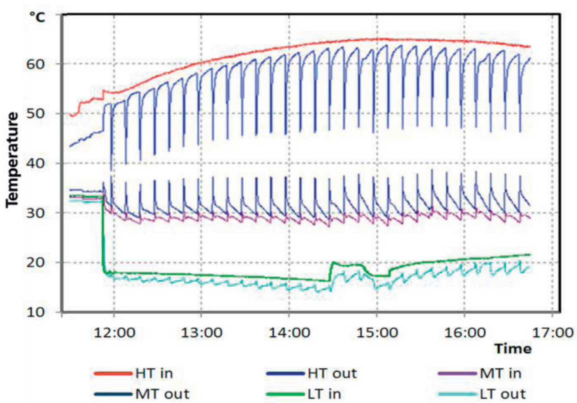

Fig. 5. Typical daily chiller temperatures of heating (HT), cooling (MT) and chilled water (LT).

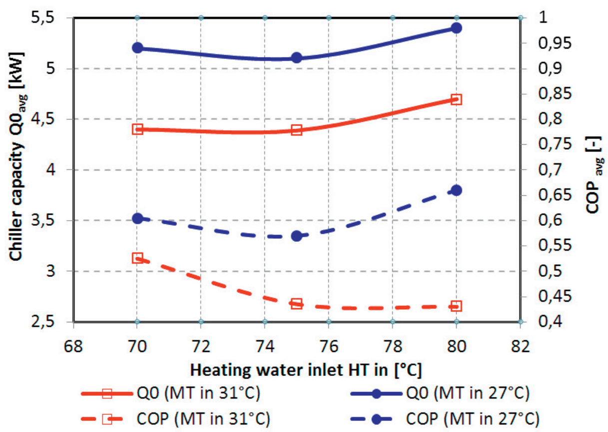

Fig. 6. Effect of the cooling water temperature on the chiller performance.

The waste heat rejection, respectively the cooling water temperature (MT), has a significant influence on the process and is a weak point of a sorption process in hot climates. An experimental test for heat rejection from the chiller was made with 27°C water from the public supply instead of 31°C water from the cooling tower. It was observed that the chiller efficiency was increased by 20-50% while the cooling capacity grew by about 15% (Fig. 6). This points out the importance of low cooling water temperatures for the chiller, or rather at the condenser and the adsorbers. Although the installed cooling tower is working well under the local conditions with low ambient rel. humidity, the cooling load is just provided by evaporation, thus consuming at least ~25 l/h (~300 l/d) of make-up water. Nevertheless, for the given conditions evaporative heat rejection is the only option. At ambient air temperatures of 38°C and more, dry coolers would lead to high cooling water temperatures and affect the sorption process severely.

Over the summer cooling period the overall solar system COP of the installation ranged from 0.25 to 0.3.

5. Outlook

At Assiut, the first solar cooling season ended in September 2012, followed by detailed evaluation of the system behaviour. During the non-cooling season maintenance work and some system modifications were conducted. In April 2013, the system operation started again for the next cooling season and monitoring.

Based on the results of the solar cooling installation in Assiut, the overall process layout will be evaluated, re-designed and adapted to other local conditions in Egypt, where similar systems could be established.

Acknowledgement

The authors gratefully acknowledge the International Bureau of the German Federal Ministry of Education and Research as well as the STDF in Egypt for funding the project “Solar Cooling Assiut” IB 08/012 within its 2008 Program for Bilateral Cooperation in Education and Research with Egypt.

References

[1] Jakob U, Solar thermisch betriebene Kühlsysteme, Conference paper, BAU 2007 - ClimaDesign meets Visions of Glass, January 17th, 2007, Munich, Germany.

[2] Reda AM, Ali AHH, Taha IS, Abdel-Moez MN, Morsy MG and Schwerdt P, Performance Assessment of a Solar Powered Residential Scale Adsorption Cooling System at Assiut, Egypt, The Future of New and Renewable Energy in Arab World, Conference paper, February 12th – 14th, 2013, Assiut, EGYPT.

[3] SorTech AG, Kälte aus Wärme, KI – Kälte, Luft, Klimatechnik, 04 (2012) 44-45.